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PROCESS TO CORRECT THE TRAJECTORY OF A SPIN-STABILISED PROJECTILE AND PROJECTILE IMPLEMENTING SUCH A PROCESS

The technical scope of the invention is that of processes and devices to ensure the correction of the trajectory of a spin-stabilised projectile.

It is known, namely by patents EP887613 and FR2792400 to make corrections to the trajectory of an artillery projectile by deploying at a given time flaps ensuring aerodynamic braking.

This deployment is controlled during the trajectory at a given time programmed before firing or during the trajectory, or else at a time during the trajectory that is determined according to the coordinates of the target and the coordinates of the projectile (measured by an inertia unit or global positioning system (GPS)).

Such a process allows the range of the projectile to be modified, thus enabling the correction of any errors due to the variations in initial velocity that are linked essentially to the firing conditions (atmospherical conditions, temperature, propellant powder dispersion characteristics, gun barrel wear…).

This process allows only the range of the projectile to be corrected. It does not correct the lateral drift of a spin-stabilised projectile.

It is known for a spin-stabilised projectile to have a lateral drift movement with respect to the firing axis, such movement being essentially due to the fact that the projectile has a longitudinal axis at an angle with respect to its velocity vector.

This angle is naturally adopted by the projectile and allows it to balance the gyroscopic torque to which it is subjected. It is proportional to the velocity of the projectile's spin rate and to its roll moment of inertia. It is also inversely proportional to the projectile's static margin, that is, to the distance separating the projectile's centre of gravity from the aerodynamic centre.

The induced drift reaches 300 m to 800m for ranges from 15 km to 25 km. This drift also varies according to the firing conditions (dispersion on the projectile's spin rate, side wind...).

It is known by patent WO02061363 to correct this drift by deploying aerodynamic fins to brake the spin. These fins are placed at the nose cone, or at a median part of the projectile body or else on the base.

Such a solution is difficult to implement and does not provided sufficient correction for the drift. The fin surface area is reduced and is thus only able to ensure moderate braking of the spin. Moreover, stronger braking of the roll is likely to destabilise the projectile.

Patent FR2764689 describes another solution in which the deployable fins are placed at the base of the projectile. These fins also ensure moderate braking of the spin but, because of their position to the rear of the projectile, they mainly act on the reduction of the projectile's static margin, thereby enabling an increase in drift.

This solution also has drawbacks.

The fins are mechanically complex and fragile. It is thus difficult to position them on a part of the projectile that is subjected to propellant gases pressure, and thus which is under great mechanical stress.

The arrangement of the fins at the rear end of the projectile also makes the latter more difficult to integrate and assemble.

Indeed, the fins are far from the projectile's nose cone, which generally carries the fuse controlling priming and which incorporates the electronic control means. Controlling the fins from the fuse thus requires the installation of an electrical connection between the front and rear of the projectile further complicating the manufacture of such a projectile.

The aim of this invention is to propose a correction process for the trajectory of a spin-stabilised projectile that does not suffer from such drawbacks.

The process according to the invention is easy to implement. It enables the manufacture of projectiles whose drift may be corrected using a simple device that is easy to integrate into a projectile, and even into an existing projectile.

Thus, the invention relates to a process to correct the trajectory of a spin-stabilised projectile, process in which at least one correction is made to the axial position of the projectile's centre of aerodynamic thrust, such process wherein the correction of the axial position of the centre of thrust is obtained by modifying at least once the length of the projectile in flight, such modification being triggered by control means.

According to one embodiment of the invention, the modification of the projectile's length in flight may be obtained by ejecting one section of the projectile.

The section thus ejected will advantageously be positioned at the front part of the projectile.

According to another embodiment of the invention, the modification of the projectile's length in flight may be obtained by the relative translation of a front part of the projectile with respect to a rear part.

Advantageously, at least one correction of the projectile's trajectory may be made by deploying projectile's aerodynamic braking means.

The invention also relates to a projectile implementing such a process. This projectile incorporates means of simple design ensuring at least one correction of its drift during trajectory.

Thus, the projectile may incorporate at least one section made integral with a projectile body by releasable linking means.

According to one embodiment of the invention, the section releasable on trajectory may be a cap placed at the front part of the projectile.

Thus, the projectile may incorporate a telescopic nose cone mounted able to slide with respect to the projectile body, such nose cone constituting a front part of the

projectile and able to move with respect to a rear part formed by the projectile body, the nose cone being made integral with the body by releasable linking means.

The nose cone may enclose a gas generator to be initiated on trajectory by the control means, the gas pressure causing the nose cone/body linking means to shear and the nose cone to translate forwards up to an abutment and thus elongating the projectile.

According to another variant, the releasable linking means are activated by the control means and the release of the nose cone allows it to translate to the rear with respect to the body under the effect of the aerodynamic pressure, thereby shortening the projectile.

According to another embodiment, the projectile incorporates a base mounted able to slide with respect to the projectile body, such base constituting a rear part of the projectile and able to move with respect to a front part formed by the projectile body, said base being made integral with the body by releasable linking means.

Advantageously, the projectile may incorporate at least one flap whose radial deployment will be triggered by the control means, such flap ensuring the aerodynamic braking of the projectile and the shortening of its range.

The invention will become more apparent from the following description of the different embodiment, such description made with reference to the appended drawings, in which:

- Figures 1a and 1b schematise a first embodiment of a projectile according to the invention, Figure 1a showing the projectile before correction and Figure 1b after correction,
- Figures 2a and 2b schematise a second embodiment of a projectile according to the invention, Figure 2a showing the projectile before correction and Figure 2b after correction,
- Figures 3a and 3b schematise a third embodiment of a projectile according to the invention, Figure 3a showing the projectile before correction and Figure 3b after correction,

- Figures 4a and 4b schematise a fourth embodiment of a projectile according to the invention, Figure 4a showing the projectile before correction and Figure 4b after correction,

- Figures 5a and 5b are diagrams showing drift corrections that may be obtained using the process according to the invention,

- Figures 6a, 6b and 6c show a fifth embodiment of a projectile according to the invention, Figure 6a showing the projectile before correction, Figure 6b after correction of the drift and Figure 6c after correction of the range,

- Figures 7a, 7b and 7c show a sixth embodiment of a projectile according to the invention, Figure 7a showing the projectile before correction, Figure 7b after correction of the drift and Figure 7c after correction of the range,

- Figure 8 is a diagram showing the range of correction that may be obtained with a projectile incorporating a device to correct the range and the drift.

With reference to Figures 1a and 1b, a projectile 1 according to a first embodiment of the invention and implementing the correction process according to the invention comprises a body 2, which is not shown in detail and which incorporates an explosive placed in a casing and ignited by a fuse 3, for example a proximity or timer fuse. The body 2 may alternatively enclose a scatterable payload, for example sub-munitions.

This projectile is, for example, a 155 mm artillery shell.

According to this embodiment of the invention, the projectile incorporates a cap 4 placed at a front part of the projectile. This cap forms a section of the projectile 1 which is linked to its body 2 by releasable linking means, for example a shearable pin 5.

The cap 4 encloses a gas-generating pyrotechnic charge 6 which may be ignited by electronic control means 7.

These control means will, for example, incorporate a microprocessor, programmed before firing or on trajectory, and which will cause the ignition, at a required time, of the pyrotechnic charge 6.

The pressure of the gases generated by the latter will cause the linking means 5 to shear, leading to the ejection of the cap 4 on trajectory.

The ejection of the cap 4 results in a modification to the length of the projectile 1 in flight (here the projectile is shortening).

This results in a modification of the static margin of the projectile 1, that is to say of the distance separating the projectile's centre of gravity G from the aerodynamic centre F. The initial static margin is written D0, the final static margin is written D1.

The ejection of the cap causes a reduction in the static margin (D1 < D0). This results in an increase in the projectile's drift.

Thus, with a 155 mm projectile fitted with a 400 mm long aluminium cap, it is possible for a reduction of 10 to 15% to be obtained in the static margin thereby increasing the drift at 25 km to almost 100 m.

In practical terms, only one correction is possible here. Firing tables are thus established allowing the definition, for a given projectile geometry and given firing conditions, the families of drift curves obtained as a function of the distance between the projectile and the weapon and as a function of the times at which the static margin of the projectile is modified.

By selecting a particular modification time of the static margin, it will be possible therefore to correct the point of impact upon the ground.

Since the drift is always oriented in the same direction for a given projectile spin direction, the projectile will be fired with a systematic azimuth laying correction of the weapon, such correction being carried out in the opposite direction to that of the drift.

By way of example, for a 155 mm projectile having an initial velocity of 810 m/s, a mass of 42 kg fired at an elevation angle of 50°, the invention allows the static margin to be reduced by 15% thereby resulting in a drift deviation of 100 m at 25 km. The maximal potential for

adjustment of the drift is 100 m and depends on the time at which the ejection of the cap is triggered.

Figure 5a thus shows a drift curve family corresponding to such a reduction in the static margin. The lowest curve (C1) corresponds to the projectile fired without ejection of the cap (maximal static margin). The highest curve (C4) corresponds to the projectile fired with ejection of the cap after 10 seconds flight time, corresponding to the maximum drift that may be obtained. The intermediate curves correspond to drifts obtained for cap ejections triggered respectively after 40 secs (curve C2) and 20 secs (curve C3). It is thus possible to make the lateral drift vary by as much as 100 m at 25 km. The embodiment in Figures 1a and 1b provides for the axial position of the centre of thrust to be modified by ejecting part of the projectile (the cap).

According to preferred embodiments of the invention the length of the projectile will be modified at least once in flight by triggering, not an ejection of a part of the projectile, but a relative translation of a front part of the projectile with respect to a rear part.

According to the embodiment in Figures 2a and 2b, the projectile 1 incorporates a body 2 shown here schematically and enclosing an explosive or other scatterable payload (sub-munitions, for example). The explosive will be ignited (or the payload scattered) by the fuse in a known manner, not shown here. A detonator or scattering charge may be provided, for example, integral with the body 2 and connected by wires to the fuse.

The body 2 incorporates an external cylindrical seat 10 on which a nose cone 11, fitted with the fuse 3, is positioned and able to slide.

The nose cone is made integral with the body by at least one transversal shearable pin 12 which constitutes releasable linking means.

The nose cone 11 encloses a gas-generating pyrotechnic charge 13 which may be ignited by electronic control means integrated in the fuse 3.

These means will incorporate, for example, a microprocessor, programmed before firing or on trajectory, and which will cause the ignition at a required time of the pyrotechnic charge 13.

The gas pressure generated by the latter will cause the linking means 12 to shear and the nose cone 11 to translate forwards (in direction F1), and will thus elongate the projectile.

The nose cone translates forwards, guided by at least one radial pin 14 which slides in a groove 15 made in the nose cone 11 (three radial pins evenly spaced angularly will preferably be provided).

Pin 14 constitutes an axial abutment limiting the translation of the nose cone forwards.

Thus, according to this embodiment, the telescopic nose cone constitutes a front part of the projectile able to move with respect to a rear part formed by the projectile body. The mass of the nose cone is reduced with respect to the total mass of the projectile; the displacement of the centre of gravity G is thus negligible with respect to that of the aerodynamic centre F. The initial static margin D0 is lower than the final static margin D1.

This results in a reduction of the projectile's drift. Once again, firing tables will be established enabling the definition, for a given projectile geometry and given firing conditions, the families of drift curves obtained as a function of the distance between the projectile and the weapon and as a function of the times at which the static margin of the projectile is modified.

Figure 5b shows the drift curve family corresponding to such an increase in the static margin. The highest curve (C'1) corresponds to the projectile being fired with no translation of the nose cone (minimal static margin). The lower curve corresponds to the projectile being fired with a translation of the nose cone after 10 seconds flight time, which corresponds to the minimal drift that may be obtained. The intermediate curves correspond to drifts obtained for translations of the nose cone triggered respectively after 20

secs (curve C'3) and 40 secs (curve C'2). It is thus possible to make the lateral drift vary by as much as 100 m at 25 km. In practical terms, for a 155 mm projectile having an initial velocity of 810 m/s, a mass of 42 kg, fired at an elevation angle of 50°, the invention allows the static margin to be increased by 15% leading to a drift of 100 m at 25 km. The maximal potential for adjustment of the drift is 100 m and depends on the time at which the translation of the nose cone is triggered.

Figures 3a and 3b show another embodiment that differs from the previous one in that the releasable linking means are constituted by a pyrotechnic retractor 16 (shown schematically integral with the body 2 and with its sliding locking rod 16a engaged in the nose cone 11). This retractor ensures the nose cone 11 is held in its advanced position shown in Figure 4a.

When the control means incorporated into the fuse 3 activate the retractor 16 on trajectory, the rod 16a is displaced and the nose cone 11 is released. It thus slides on the cylindrical seat 10 in direction F2, thus towards the rear of the projectile, under the effect of the aerodynamic pressure exerted on the projectile in flight.

This results in a shortening of the projectile 1 and a reduction of the static margin. The initial static margin D0 is greater than the final static margin D1, causing an increase in the projectile's drift. The drift curve family is thus analogous to that in Figure 5a. The drift may once again be corrected by as much as 100 m at 25 km.

Figures 4a and 4b show a projectile according to a fourth embodiment of the invention.

This projectile 1 is once again shown schematically. It incorporates a body 2, not shown in detail, which will incorporate an explosive placed in a casing and ignited by a nose cone fuse 3, for example a proximity or timer fuse. The body 2 may also enclose a scatterable payload, for example sub-munitions.

The projectile 1 incorporates a base 8 mounted able to slide on an external cylindrical seat 18 arranged on the outside of the body 2.

The base 8 is made integral with the body 2 by at least one shearable transversal pin 19 which constitutes releasable linking means.

A gas-generating pyrotechnic charge 20 is arranged in a housing to the rear of the projectile body. This charge may be ignited by electronic control means 21. These are shown here near the charge 20. They may alternatively be integrated into the fuse 3 and connected to a squib (not shown) of the charge 20 by connecting wires.

The control means will, for example, incorporate a microprocessor, programmed before firing or on trajectory, and which will cause, at a required moment, the ignition of the pyrotechnic charge 20.

The gas pressure generated by the charge 20 will cause the linking means 19 to shear and the base 8 to translate rearwards (in direction F3), and will thus elongate the projectile.

The base 8 translates rearwards guided by at least one radial pin 22 sliding in a groove 23 made in the base 8 (preferably, three radial pins evenly spaced angularly will be provided).

The pin 22 constitutes an axial abutment which limits the translation of the base 8 rearwards.

Thus, according to this embodiment, the base constitutes a rear part of the projectile able to move with respect to a front part formed of the projectile body.

This device allows the static margin to be reduced because the aerodynamic centre is pushed back towards the rear of the projectile without the position of the centre of gravity G being significantly modified (mass of the base being much lower than the total mass of the projectile). The initial static margin D0 is thus greater than the final static margin D1.

This results in an increase of the projectile's drift. The drift curve family is analogous to that shown in Figure 5a.

The previously described embodiments enable corrections to be made only on the drift of a projectile.

It will be advantageous to combine them with means enabling a correction in the range to be made.

Such means are known, namely by patents EP887613, FR2786561 and FR2792400.

They comprise flaps carried by a fuse and deployed at a given time on trajectory to increase the projectile's aerodynamic drag.

Figures 6a, 6b and 6c show an embodiment of a projectile 1 according to the invention and incorporating means to correct the range and means to correct the drift.

In this embodiment the correction in drift is obtained using the solution described previously with reference to Figures 3a and 3b. A telescopic nose cone 11 is made integral with the projectile body 3 by releasable linking means 16, formed of a pyrotechnic retractor. At a given time on trajectory, the retractor 16 is activated by the fuse 3, the nose cone translates rearwards and the projectile 1 is shortened (Figure 6b).

The static margin is reduced (D1<D0) thereby increasing the projectile's drift.

At another time on trajectory, the fuse 3 triggers the radial deployment of flaps 17. These flaps ensure the aerodynamic braking of the projectile, thus the shortening of its trajectory. The mechanical structure of the flaps is not described in detail and reference may be made to either patent FR2786561 or patent FR2792400 to obtain further details on such a structure.

By acting on the relative triggering times of the telescopic nose cone (drift correction) and the aerodynamic flaps (range correction) it is possible to make two successive corrections to the trajectory enabling a point of impact on the ground to be obtained located in a substantial range of adjustment.

By way of example, Figure 8 shows the range of adjustment which may be obtained for a 155 mm artillery shell with a mass of 42 kg fired at an initial velocity of 810 m/s at an elevation angle of 50°. This shell is fitted with a retractable nose cone allowing the static margin to be reduced by 15% and comprises deployable flaps that double the projectile's drag.

We see that the projectile according to the invention enables the range to be varied within a range of 500 m and the drift within a range of 100 m.

Figures 7a, 7b and 7c show another embodiment of the invention which combines range and drift correction. This embodiment differs from the previous one in that the drift correction is obtained using the solution described previously with reference to Figures 2a and 2b. The telescopic nose cone 11 is made integral with the projectile body 2 by releasable linking means 12 formed by a pin that can be sheared by the gas pressure generated by a pyrotechnic gas-generator 13. At a given time on trajectory, the generator 13 is triggered by the fuse 3, the nose cone translates forwards and the projectile 1 elongates (Figure 7b).

The static margin is increased (D1>D0) thereby reducing the projectile's drift.

At another time on trajectory, the fuse 3 triggers the radial deployment of flaps 17. These flaps ensure the aerodynamic braking of the projectile, and thus the shortening of its trajectory.

By way of example, a 155 mm artillery shell with a mass of 42 kg fired at an initial velocity of 810 m/s at an elevation angle of 50° is fitted with a telescopic nose cone enabling the static margin to be increased by 15%. This shell also comprises deployable flaps that double the projectile's drag.

Such a shell enables the range to be varied within a range of 500 m and the drift within a range of 100 m.

Different variants are possible without departing from the scope of the invention.

For example, the range correction (and thus the deployment of the flaps 17) may be triggered before the drift correction by displacement of the nose cone. The range of possible corrections is analogous.

The projectile according to the embodiment in Figures 4a and 4b (projectile with sliding base) may also be fitted with a fuse having braking flaps.

In the embodiment shown in Figures 4a and 4b, a projectile may be defined whose base not only slides but is ejected on trajectory.

Lastly, a projectile may be designed in which several successive modifications to its length may be triggered on trajectory.